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(54) **POWER SUPPLY APPARATUS, POWER SUPPLY SYSTEM AND POWER SUPPLY METHOD**

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H02M 1/00 (2007.01)

(52) **U.S. Cl.**
CPC ***H02M 3/157*** (2013.01); *H02M 2001/0035* (2013.01); *Y02B 70/16* (2013.01)

(58) **Field of Classification Search**
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USPC 323/282–285
See application file for complete search history.

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(57) **ABSTRACT**

A power supply apparatus, comprising: a driver connected to a power source voltage and configured to perform an ON/OFF operation of power supply to a load; a digital control circuit configured to perform an ON/OFF control of the driver; and an oscillator configured to output an oscillator signal for performing the ON/OFF control of the driver every constant period. The digital control circuit operates in a normal control mode in which the output operation of the oscillator signal by the oscillator and the ON/OFF operation of the driver are continuously activated, or in a low power control mode in which the output operation of the oscillator signal by the oscillator and the ON/OFF operation of the driver are intermittently activated.

11 Claims, 4 Drawing Sheets

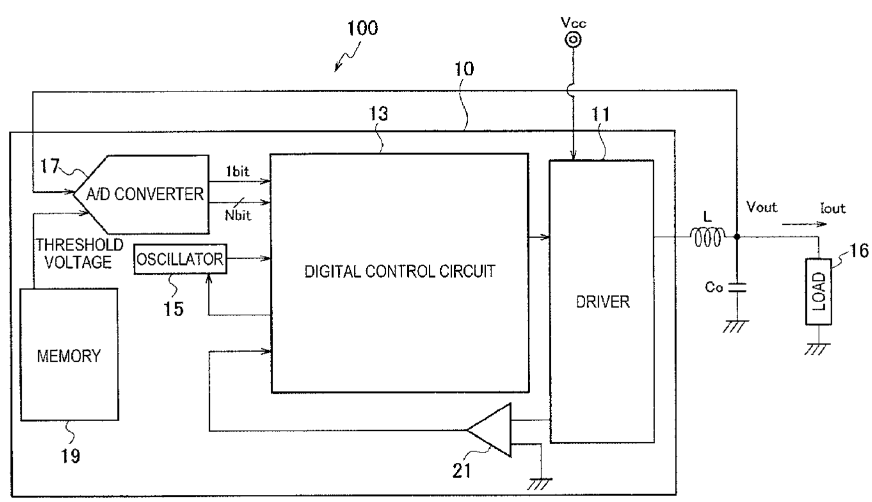


FIG. 1

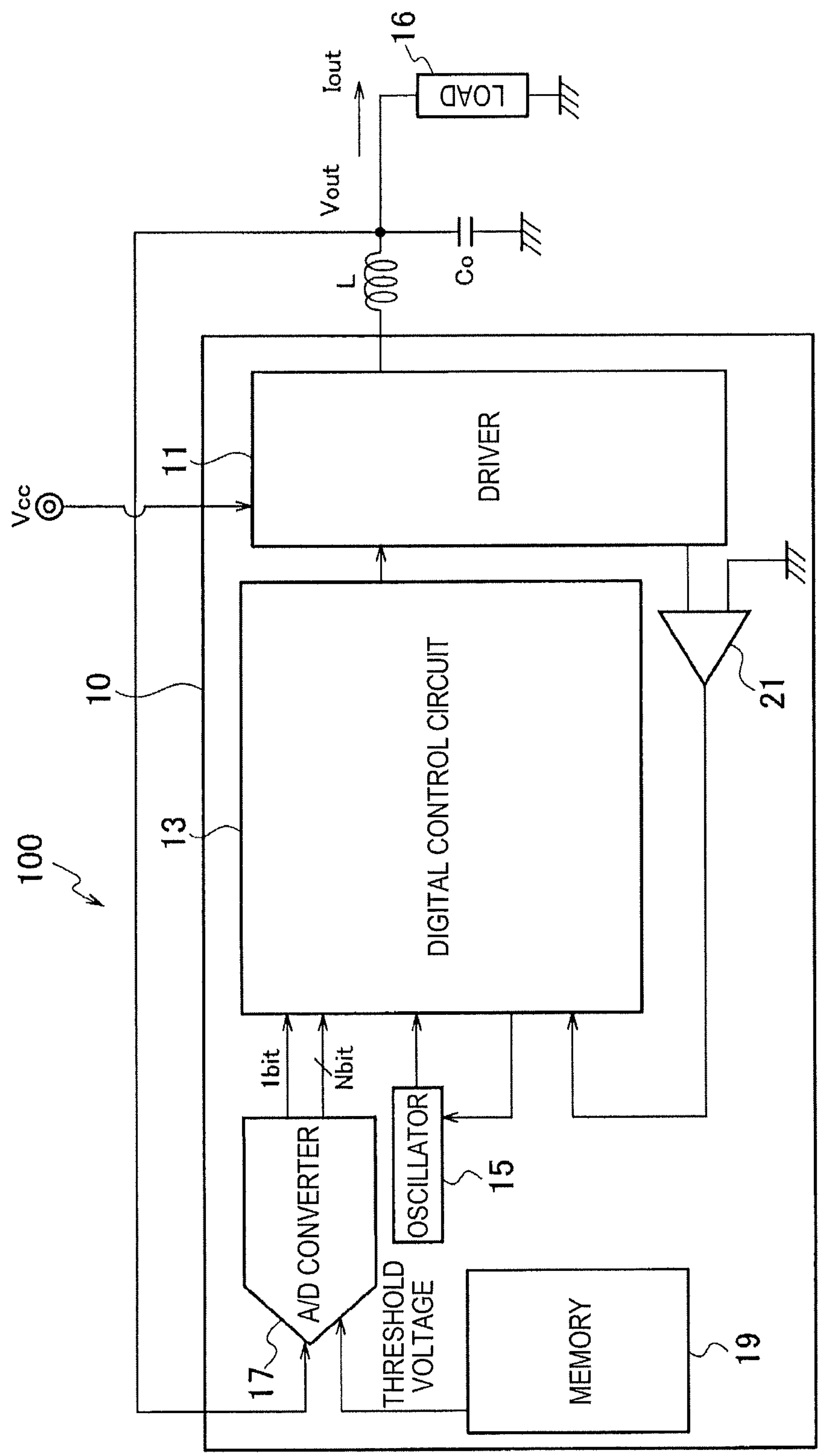

100
10
11
13
15
16
17
19
21
Iout
Vout
LOAD
L
Co
Vcc
DRIVER
DIGITAL CONTROL CIRCUIT
1bit
Nbit
OSCILLATOR
A/D CONVERTER
THRESHOLD VOLTAGE
MEMORY

FIG. 2

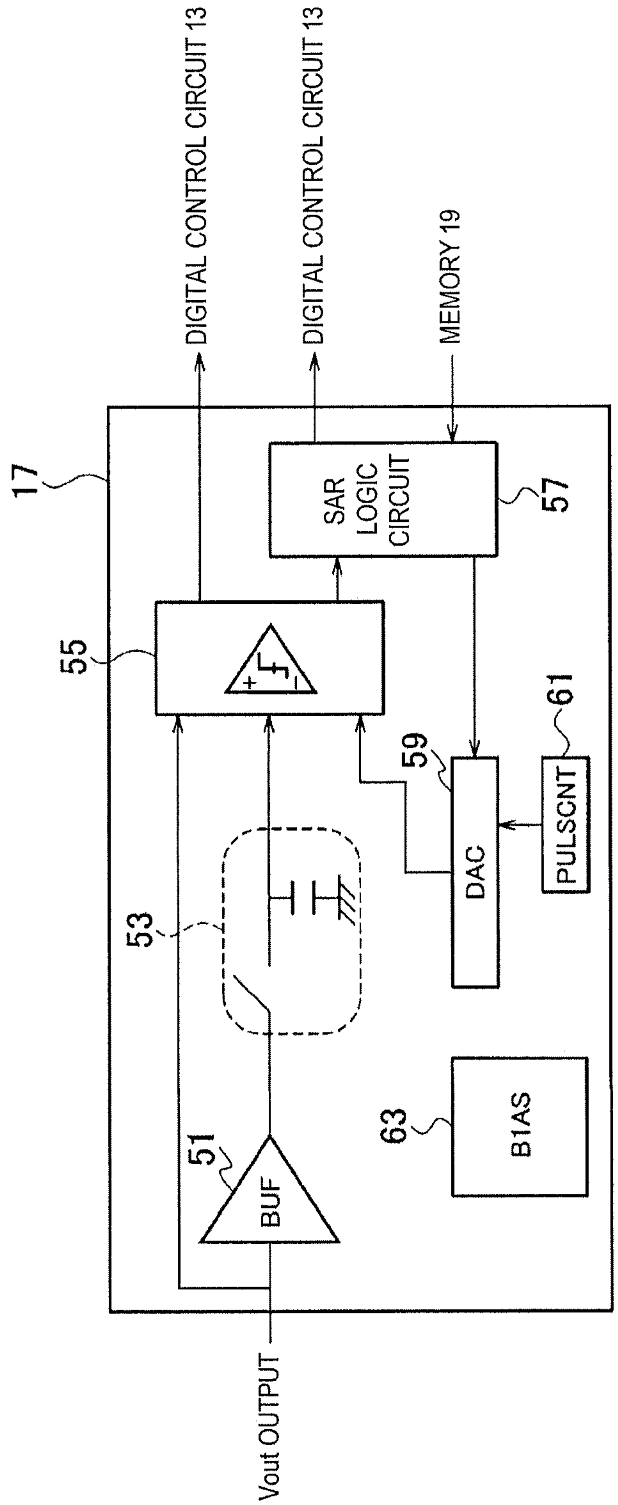

DIGITAL CONTROL CIRCUIT 13
DIGITAL CONTROL CIRCUIT 13
MEMORY 19
17
SAR LOGIC CIRCUIT
57
55
61
59
PULSCNT
DAC
53
51
BUF
63
B1AS
Vout OUTPUT

FIG. 3

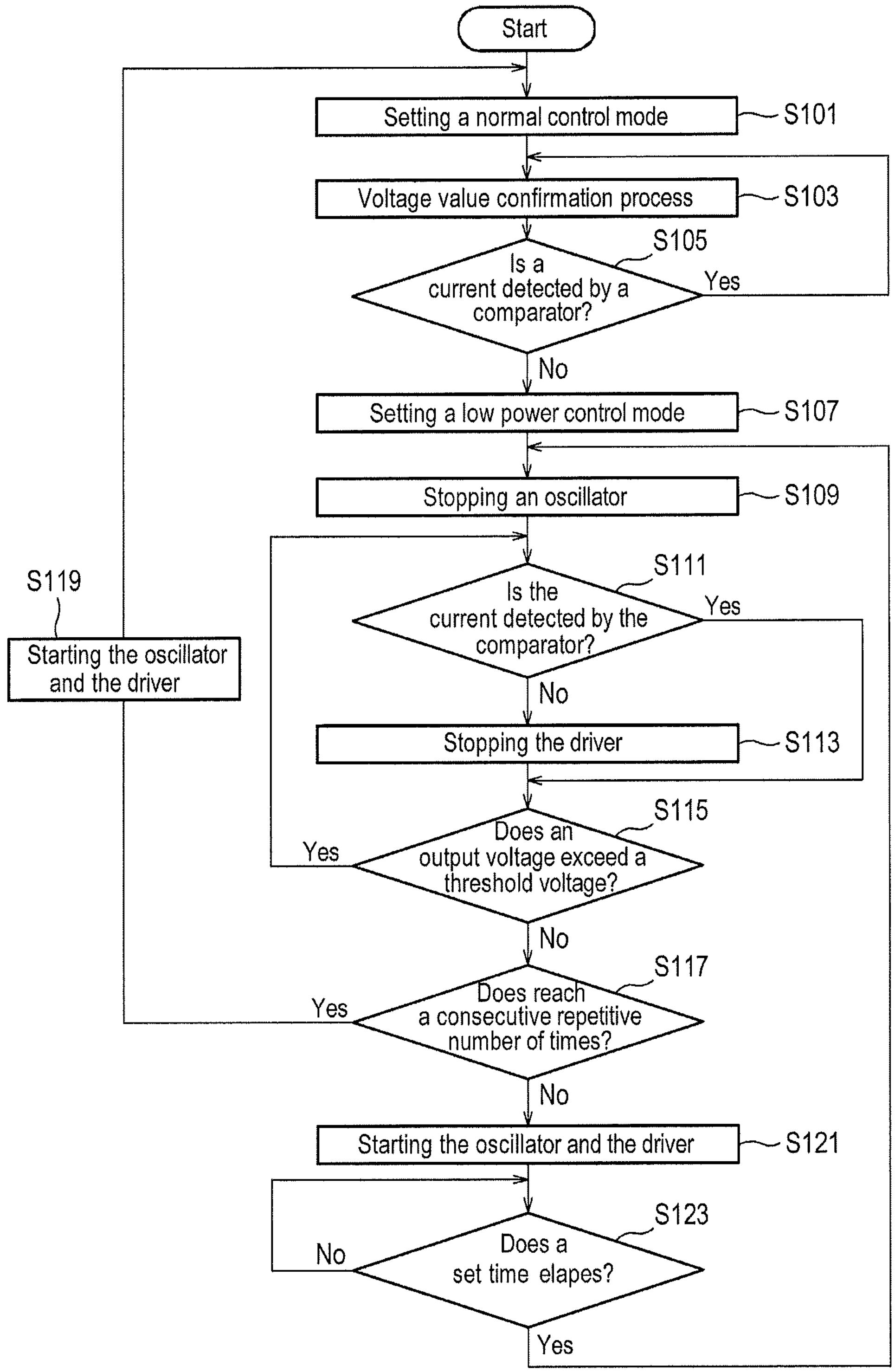
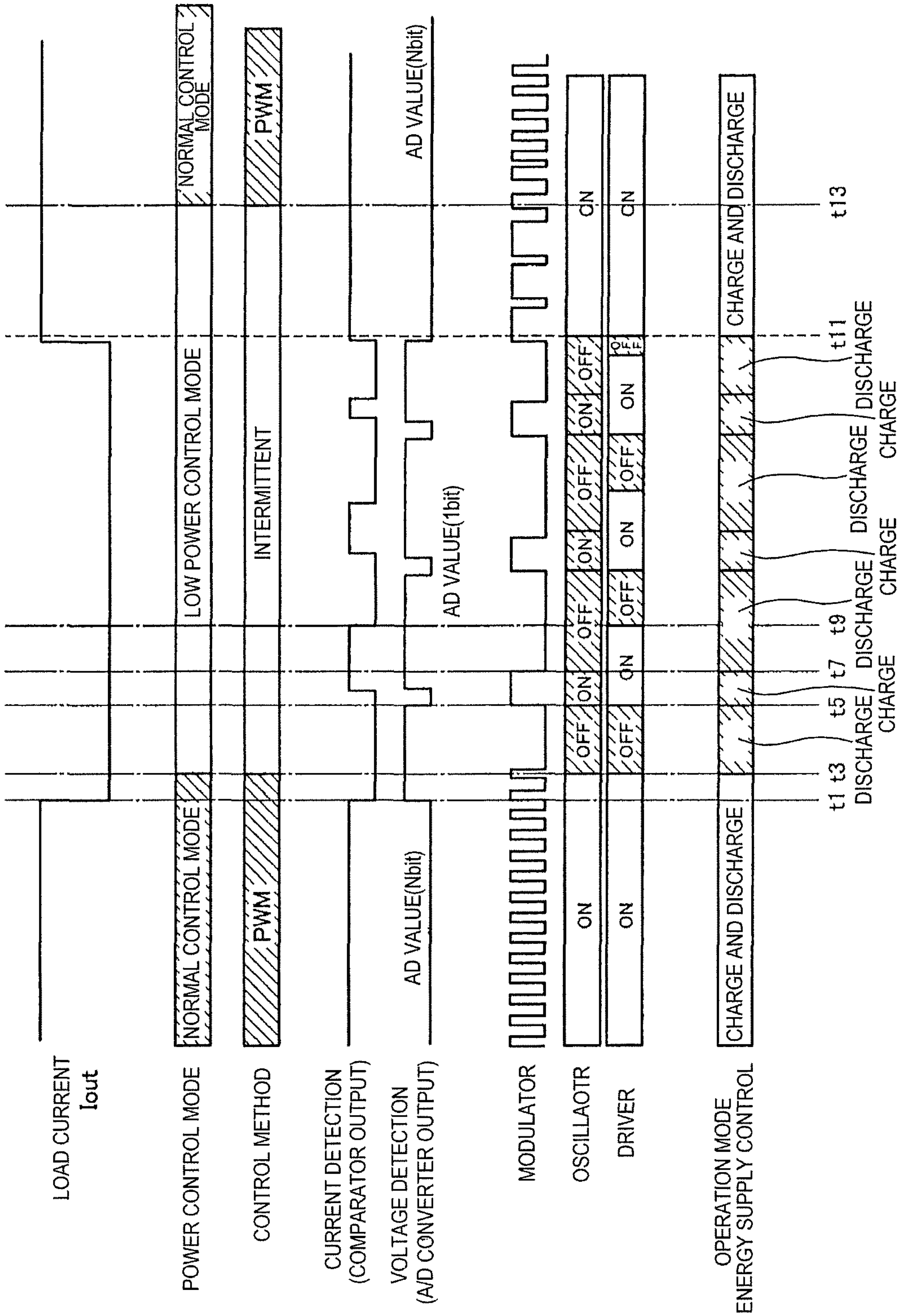

Start
Setting a normal control mode
S101
Voltage value confirmation process
S103
S105
Is a current detected by a comparator?
Yes
No
Setting a low power control mode
S107
Stopping an oscillator
S109
S111
Is the current detected by the comparator?
Yes
No
Stopping the driver
S113
S115
Does an output voltage exceed a threshold voltage?
Yes
No
S117
Does reach a consecutive repetitive number of times?
Yes
No
S119
Starting the oscillator and the driver
Starting the oscillator and the driver
S121
S123
Does a set time elapes?
No
Yes

FIG. 4


LOAD CURRENT Iout
POWER CONTROL MODE
CONTROL METHOD
CURRENT DETECTION (COMPARATOR OUTPUT)
VOLTAGE DETECTION (A/D CONVERTER OUTPUT)
MODULATOR
OSCILLAOTR
DRIVER
OPERATION MODE ENERGY SUPPLY CONTROL
NORMAL CONTROL MODE
LOW POWER CONTROL MODE
PWM
INTERMITTENT
AD VALUE(Nbit)
AD VALUE(1bit)
ON
OFF
CHARGE AND DISCHARGE
DISCHARGE
CHARGE
t1 t3
t5
t7
t9
t11
t13

POWER SUPPLY APPARATUS, POWER SUPPLY SYSTEM AND POWER SUPPLY METHOD

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2012-166654, filed on Jul. 27, 2012, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to a power supply apparatus, a power supply system and a power supply method, and in particular, to an adjustment of a setting being digitally executed (e.g., change of parameter or software) to thereby eliminate the need for a redesign according to the specifications or the environment of an equipment (a load) to which the power is being supplied, without lowering the efficiency even when a small amount of power is supplied.

BACKGROUND

Generally, in a power conversion apparatus, particularly, in an apparatus for performing a DC power conversion, a power supply apparatus that controls electric power for supplying to a load by an ON/OFF control of a switching element is well known.

The power supply apparatus may include an analog circuit system and a digital circuit system.

However, since the power supply apparatus of the conventional analog circuit system uses a switching power source realized by an analog circuit, it is difficult to change the setting of the power supply apparatus. Therefore, there is a problem when adjusting a ripple voltage or a switching frequency according to the specifications of the equipment to which power is supplied.

Further, since the power supply apparatus of the conventional digital circuit system uses a digital controller for a high frequency voltage regulator, which is implemented in a digital circuit, the power supply apparatus oscillates high frequency clock pulses. In particularly, when power consumption by the equipment to which power is supplied is small, since the power consumption of the digital controller is relatively large, there is a need to reduce the power consumption of the digital controller.

SUMMARY

Various embodiments for a power supply apparatus and a power supply method, which can execute an adjustment setting with only a digital setting (change of parameter or software) and eliminate the need for a redesign according to the specifications or the environment of the equipment to which power is supplied, without lowering the efficiency even when a small amount of power is supplied.

According to an aspect of the present disclosure, there is provided a power supply apparatus, comprising: a driver connected to a power source voltage and configured to perform an ON/OFF operation of power supply to a load; a digital control circuit configured to perform an ON/OFF control of the driver; and an oscillator configured to output an oscillator signal for performing the ON/OFF control of the driver every constant period. The digital control circuit operates in a normal control mode in which the output operation of the oscillator signal by the oscillator and the ON/OFF operation of the driver are continuously activated, or in a low power control mode in which the output operation of the oscillator signal by the oscillator and the ON/OFF operation of the driver are intermittently activated.

According to another aspect of the present disclosure, there is provided a power supply method, comprising: a digital control step of performing an ON/OFF control of a driver; and an oscillation step of outputting an oscillator signal for performing the ON/OFF control of the driver every constant period. The digital control step has a normal control mode in which the output operation of the oscillator signal by the oscillator and the ON/OFF operation of the driver are continuously activated, and a low power control mode in which the output operation of the oscillator signal by the oscillator and the ON/OFF operation of the driver are intermittently activated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram showing a configuration of a power supply system according to an embodiment.

FIG. **2** is a schematic diagram showing a configuration of an A/D converter included in a power supply apparatus of the power supply system according to the embodiment.

FIG. **3** is a flowchart showing a process procedure by the power supply apparatus of the power supply system according to the embodiment.

FIG. **4** is a timing chart of the power supply apparatus of the power supply system according to the embodiment.

DETAILED DESCRIPTION

Reference will now be made in detail to various embodiments, examples of which are illustrated in the accompanying drawings. In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the present invention(s). However, it will be apparent to one of ordinary skill in the art that the present invention(s) may be practiced without these specific details. In other instances, well-known methods, procedures, systems, and components have not been described in detail so as not to unnecessarily obscure aspects of the various embodiments.

Next, embodiments of the present disclosure will be described with reference to the drawings. Throughout the drawings, same or similar elements are denoted by same or similar reference numerals.

The following embodiments are provided to illustrate devices and methods to embody the technical ideas of the present disclosure and are not intended to limit material, shape, structure, arrangement and so on of elements to those recited in the disclosed embodiments of the present disclosure. The disclosed embodiments may be modified in various ways without departing from the spirit and scope of the present disclosure set forth in the claims.

(Outline of Power Supply System)

FIG. **1** is a schematic diagram showing a configuration of a power supply system **100** according to an embodiment. As shown in FIG. **1**, the power supply system **100** according to the embodiment includes a power supply apparatus **10**, a coil L, a capacitor Co and a load **16**. For example, the power supply apparatus **10** is a switching power source apparatus. The coil L is connected to the power supply apparatus **10**. The capacitor Co and the load **16** are connected to the coil L. A power source voltage Vcc is inputted to the power supply apparatus **10** as an input power source voltage, and an output voltage Vout is outputted from a connection node of the capacitor Co and the coil L.

The power supply apparatus **10** is connected to the load **16** to supply power to the load **16**. The load **16** may be, for example, a mobile apparatus including a cellular phone, a smartphone, a personal digital assistant (PDA), an optical disk apparatus, a digital camera, a wireless communication apparatus and the like, or components thereof.

The power supply apparatus **10** includes a driver **11**, a digital control circuit **13**, an oscillator **15** and a comparator **21**. The driver **11** is connected to the power source voltage Vcc and performs an ON/OFF operation of the power supply to the load **16**. The digital control circuit **13** performs an ON/OFF control of the driver **11**. The oscillator **15** outputs an oscillator signal for turning on/off the driver **11** to the digital control circuit **13** every constant period, for example, every clock period of 1 MHz. The comparator **21** detects an output current of the driver **11**.

The digital control circuit **13** has a normal control mode and a low power control mode. In the normal control mode, an output operation of the oscillator signal by the oscillator **15** and the ON/OFF operation of the driver **11** are performed continuously. In the low power control mode, the output operation of the oscillator signal by the oscillator **15** and the ON/OFF operation of the driver **11** are performed intermittently.

The digital control circuit **13** sets the switching between the normal control mode and the low power control mode based on a current detected by the comparator **21**, and controls the driver **11** and the oscillator **15** based on the set control mode.

The digital control circuit **13** stops the output operation of the oscillator signal by the oscillator **15** and the ON/OFF operation of the driver **11** when the digital control circuit **13** is switched from the normal control mode to the low power control mode. Specifically, the digital control circuit **13** is switched from a continuous operation state in the normal control mode to an intermittent operation state in the in low power control mode only when it is necessary.

The oscillator **15** outputs the oscillator signal (clock period signal) for turning ON/OFF the driver **11** to the digital control circuit **13**. The oscillator **15** has a function of turning on and off the output of the oscillator signal. The oscillator **15** continuously outputs the clock period signal (always EN signal ON) in the normal control mode, and intermittently outputs the clock period signal in the low power control mode. That is, the oscillator **15** outputs the clock period signal when the EN signal is ON and stops the clock period signal when the EN signal is OFF in the low power control mode, thereby enabling an intermittent operation.

The power supply apparatus **10** includes an A/D converter **17**. The A/D converter **17** compares the output voltage Vout outputted from the connection node of the coil L, which is current controlled by the driver **11**, and the capacitor Co, which is connected to the coil L, with a predetermined threshold voltage VTH.

The digital control circuit **13** starts the ON/OFF operation of the driver **11** when the low power control mode is set and the output voltage Vout is equal to or less than the threshold voltage VTH by a comparison result of the A/D converter **17**.

The digital control circuit **13** stops the output operation of the oscillator signal by the oscillator **15** and then activates the output operation after a predetermined time, when the low power control mode is set.

Specifically, the digital control circuit **13** turns on the driver **11** immediately when the output operation of the oscillator signal of the oscillator **15** is stopped and a lowered voltage condition (i.e., the condition that the output voltage Vout is equal to or less than the threshold voltage VTH) is detected by the A/D converter **17**. When the driver **11** is activated for the predetermined time and the output value of the A/D converter **17** is reversed (i.e., the output voltage Vout becomes equal to or more than the threshold voltage VTH), the digital control circuit **13** turns off the driver **11**. That is, the digital control circuit **13** activates the output operation of the oscillator signal of the oscillator **15** for the predetermined time, and stops the output operation when the output voltage Vout is determined to be equal to or more than the threshold voltage VTH by the comparison result of the A/D converter **17**. The ON/OFF operation may be repeated for the predetermined time.

When the low power control mode is set, the digital control circuit **13** activates the output operation and sets the normal control mode if the number of times that the output operation of the oscillator signal by the oscillator **15** is consecutively stopped reaches a predetermined consecutive repetitive number of times. That is, the control mode of the digital control circuit **13** is switched from the low power control mode to the normal control mode and a continuous operation is performed, when the number of times that the output operation of the oscillator signal by the oscillator **15** is consecutively stopped reaches the predetermined consecutive repetitive number of times.

(Detailed Configuration of Power Supply Apparatus)

The configuration of the power supply apparatus **10** of the power supply system according to the embodiment will be described in detail.

As shown in FIG. **1**, a schematic circuit configuration of the power supply apparatus **10** includes the driver **11**, the digital control circuit **13**, the coil L, the capacitor Co, the oscillator (OSC) **15**, the A/D converter **17**, a memory **19** and the comparator **21**. The driver **11** is connected to the power source voltage Vcc and performs the ON/OFF operation. The digital control circuit **13** performs the ON/OFF control of the driver **11**. The coil L controls the amount of current that flows to the driver **11**. The capacitor Co is connected to the coil L and performs a rectification operation together with the coil L. The oscillator **15** outputs the oscillator signal for performing the ON/OFF control of the driver **11** every constant period such as the clock period of 1 MHz. The A/D converter **17** compares the output voltage Vout outputted from the connection node of the capacitor Co and the coil L with the predetermined threshold voltage VTH. The memory **19** supplies the threshold voltage VTH to the A/D converter **17**. The comparator **21** detects the output current of the driver **11**.

Also, the driver **11** has a switch element (not shown) and turns on/off the switch element. For example, the switch element may be configured by a CMOSFET (Complementary Metal Oxide Semiconductor Field Effect Transistor) including a P channel MOSFET whose drain is connected to the coil L and source is connected to the power source voltage Vcc, and an N channel MOSFET whose drain is connected to the coil L and source is connected to a ground potential.

The digital control circuit **13** operates in the normal control mode or the low power control mode. The normal control mode is a control mode in which the output operation of the oscillator signal by the oscillator **15** and the ON/OFF operation of the driver **11** are continuously activated. The low power control mode is a control mode in which the output operation of the oscillator signal by the oscillator **15** and the ON/OFF operation of the driver **11** are activated intermittently. Since the low power control mode intermittently activates the output operation of the oscillator signal by the oscillator **15** and the ON/OFF operation of the driver **11**, the low power control mode can reduce the power consumption in comparison with the normal control mode.

The digital control circuit **13** sets to switch between the normal control mode and the low power control mode based on the current detected by the comparator **21**, and controls the driver **11** and the oscillator **15** based on the set control mode.

Specifically, the digital control circuit **13** stops the output operation of the oscillator signal by the oscillator **15** and the ON/OFF operation of the driver **11** when the control mode is switched from the normal control mode to the low power control mode. Also, the digital control circuit **13** starts the ON/OFF operation of the driver **11** when the low power control mode is set and the output voltage Vout is determined to be equal to or less than the threshold voltage VTH by the comparison result of the A/D converter **17**.

The A/D converter **17** also includes a low power function, which is switched from an n bit conversion to a 1 bit conversion when the control mode is switched from the normal mode to the low power mode. That is, the A/D converter **17** operates in an n bit mode (e.g., 10 bit mode), which performs the A/D conversion by n-bit (e.g., 10 bits), and a 1 bit mode, which compares the output voltage Vout with the threshold voltage VTH by 1-bit, as described later. The A/D converter **17** operates in the n bit mode when the normal control mode is set, and operates in the 1 bit mode when the low power control mode is set. That is, the A/D converter **17** becomes a comparator in the 1 bit mode.

Also, the digital control circuit **13** stops the output operation of the oscillator signal by the oscillator **15** and then activates the output operation after a lapse of a predetermined time, when the low power control mode is set.

Specifically, the digital control circuit **13** turns on the driver **11** immediately when the oscillator signal of the oscillator **15** is stopped and a lowered voltage condition (i.e., the condition that the output voltage Vout is equal to or less than the threshold voltage VTH) is detected by the A/D converter **17**. When the driver **11** is activated for the predetermined time and the output value of the A/D converter **17** is reversed (i.e., the output voltage Vout becomes equal to or more than the threshold voltage VTH), the digital control circuit **13** turns off the driver **11**. That is, the digital control circuit **13** activates the output operation of the oscillator signal of the oscillator **15** for the predetermined time, and stops the output operation when the output voltage VOUT is determined to be more than or equal to the threshold voltage VTH by the comparison result of the A/D converter **17**. The ON/OFF operation may be repeated for the predetermined time.

When the low power control mode is set, the digital control circuit **13** activates the output operation and sets the normal control mode if the number of times that the output operation of the oscillator signal by the oscillator **15** is consecutively stopped reaches the predetermined consecutive repetitive number of times. That is, a control mode of the digital control circuit **13** is switched from the low power control mode to the normal control mode and a continuous operation is performed, when the number of times that the output operation of the oscillator signal by the oscillator **15** is consecutively stopped reaches the predetermined consecutive repetitive number of times.

FIG. **2** is a diagram showing the A/D converter **17** included in the power supply apparatus **10** of the power supply system **100** according to the embodiment.

The A/D converter **17** operates in the n bit mode or the 1 bit mode. The A/D converter **17** compares the output voltage Vout outputted from the connection node of the capacitor CO and the coil L with the predetermined threshold voltage VTH in the 1 bit mode, when the low power control mode is set.

Specifically, the A/D converter **17** includes a buffer (BUF) **51**, an S/H circuit **53**, a comparator unit **55**, a successive approximation register (SAR) logic circuit **57**, a digital to analog converter (DAC) **59**, a pulse count generator (PULSCNT) **61** and a bias circuit **63**, as shown in FIG. **2**. The BUF **51** temporarily stores the output voltage Vout. The S/H circuit **53** stores the output voltage Vout supplied from the BUF **51**. The comparator unit **55** compares input values. The SAR logic circuit **57** temporarily stores the comparison result supplied from the comparator unit **55** and supplies the threshold voltage VTH supplied from the memory **19** to the DAC **59**. The DAC **59** converts digital signals into analog signals. The PULSCNT **61** generates a pulse count.

The A/D converter **17** operates in the n bit mode (e.g., 10 bit mode), which performs the A/D conversion by the n-bit, and the 1 bit mode, which compares the output voltage Vout with the threshold voltage VTH by the 1-bit. The A/D converter **17** operates in the n bit mode (e.g., 10 bit mode) when the normal control mode is set, and operates in the 1 bit mode when the low power control mode is set.

Also, the A/D converter **17** performs the A/D conversion of the threshold voltage VTH by looping the comparator unit **55**, the SAR logic circuit **57** and the DAC **59** about 10 times when the normal control mode is set (e.g., when operating in the 10 bit mode).

When the low power control mode is set (when operating in the 1 bit mode), the A/D converter **17** compares the output voltage Vout with the threshold voltage VTH by using the comparator unit **55**, the DAC **59**, the PULSCNT **61** and the bias circuit **63**. Specifically, the threshold voltage VTH is supplied to the comparator unit **55** through the DAC **59**, and the output voltage Vout is supplied to the comparator unit **55** from the BUF **51**.

The comparator unit **55** compares the output voltage Vout with the threshold voltage VTH. The comparator unit **55** supplies an OFF signal to the digital control circuit **13** when the output voltage Vout exceeds the threshold voltage VTH. The comparator unit **55** supplies an ON signal to the digital control circuit **13** when the output voltage Vout is equal to or less than the threshold voltage VTH.

As describe above, since the A/D converter **17** operates to switch between the n bit mode (10 bit mode), which performs the A/D conversion by the n-bit, and the 1 bit mode, which compares the output voltage Vout with the threshold voltage VTH by the 1-bit, it is possible to save hardware resources since the same hardware components may be used to realize an A/D conversion function and a comparison function.

(Operation of Power Supply Apparatus)

Next, the operation of the power supply apparatus **10** of the power supply system **100** according to the embodiment will be described.

FIG. **3** is a flowchart showing a process procedure by the power supply apparatus **10** of the power supply system **100** according to the embodiment.

(a) As shown in FIG. **3**, at first, the normal control mode is set when the power supply apparatus **10** is powered on (step S**101**). As a result, the output operation of the oscillator signal by the oscillator **15**, and various operations of each component included in the power supply apparatus **10**, for example the ON/OFF operation of the driver **11** and the like are continuously performed.

(b) Next, a voltage value confirmation process is performed (step S**103**). Herein, since the normal control mode is set, the

A/D converter **17** confirms a voltage value in the 10 bit mode. That is, the A/D converter **17** converts an analog voltage value into a digital voltage value.

(c) Next, the comparator **21** determines whether or not the output current of the driver **11** is detected (step S**105**).

(d) In the step S**105**, if it is determined that the output current of the driver **11** is detected by the comparator **21**, the process proceeds to the step S**103**. Meanwhile, if it is determined that the output current of the driver **11** is not detected, that is, the current value falls to "0 (A)", the digital control circuit **13** sets the low power control mode as the control mode (step S**107**). As a result, the output operation of the oscillator signal by the oscillator **15** and the ON/OFF operation of the driver **11** are intermittently activated.

(e) When the low power control mode is set, the output operation of the oscillator signal by the oscillator **15** is stopped (step S**109**).

(f) Then, the comparator **21** determines whether or not the output current of the driver **11** is detected (step S**111**).

(g) In the step S**111**, if it is determined that the output current of driver **11** is not detected by the comparator **21**, that is, the current value falls to "0 (A)" (NO), the digital control circuit **13** stops the ON/OFF operation of the driver **11** (step S**113**).

(h) Then, it is determined whether or not the output voltage Vout exceeds the threshold voltage VTH (step S**115**). Specifically, since the low power control mode is set, the A/D converter **17** operates in the 1 bit mode to compare the output voltage Vout with the threshold voltage VTH by using the comparator unit **55**, the DAC **59**, the PULSCNT **61** and the bias circuit **63**. The A/D converter **17** supplies the OFF signal to the digital control circuit **13** when the output voltage Vout exceeds the threshold voltage VTH, and supplies the ON signal to the digital control circuit **13** when the output voltage VOUT is equal to or less than the threshold voltage VTH.

(i) In the step S**111**, if it is determined that the output current of the driver **11** is detected, the process does not perform the step S**113** and proceeds to the step S**115**.

(j) In the step S**115**, if it is determined that the output voltage Vout exceeds the threshold voltage VTH (YES), that is, the OFF signal is supplied to the digital control circuit **13**, the process proceeds to the step S**111**.

(k) In the step S**115**, if it is determined that the output voltage Vout is equal to or less than the threshold value VTH (NO), that is, the ON signal is supplied to the digital control circuit **13**, the digital control circuit **13** determines whether or not the number of times that the output operation has been consecutively stopped reaches the consecutive repetitive number of times (step S**117**). Herein, the consecutive repetitive number of times is an upper limit of the number of times that the output operation of the oscillator signal is executed by the oscillator **15**, which operates intermittently, when the low power control mode is set. The consecutive repetitive number of times may be set previously. That is, the consecutive repetitive number of times means the number of times that the output operation of the oscillator signal by the oscillator **15**, which operates intermittently and is turned on only for predetermined time duration, is repeated consecutively. The set period of the low power control mode is determined by the consecutive repetitive number of times. Herein, the consecutive repetitive number of times is set as "3".

(l) In the step S**117**, if it is determined that the number of times the output operation is consecutively stopped reaches the consecutive repetitive number of the times (YES), the output operation of the oscillator signal by the oscillator **15** and the ON/OFF operation of the driver **11** are started (step S**119**).

(m) In the step S**117**, if it is determined that the number of times the output operation is consecutively stopped is equal to or less than the consecutive repetitive number of times (NO), the output operation of the oscillator signal by the oscillator **15** and the ON/OFF operation of the driver **11** are started (step S**121**), and then it is determined whether or not a set time elapses (step S**123**). The set time is a time between the start of the output operation of the oscillator signal of the oscillator **15** and the stop of the output operation of the oscillator signal of the oscillator **15**, when the low power control mode is set. The set time is a predetermined time.

FIG. **4** is a timing chart of the power supply apparatus **10** of the power supply system **100** according to the embodiment.

As shown in FIG. **4**, when the output current of the driver **11** is not detected by the comparator **21**, that is, the output signal of the comparator **21** becomes a low level at time t**1**, the control mode is switched from the normal control mode to the low power control mode at time t**3**.

As a result, the output operation of the oscillator signal by the oscillator **15** and the ON/OFF operation of the driver **11** are stopped. Since the power supply is stopped as the ON/OFF operation of the driver **11** is stopped, a self-discharge of the capacitor Co is started.

At time t**5**, when the output voltage Vout is equal to or less than the threshold voltage VTH and the output signal from the A/D converter **17** becomes a low level, the output operation of the oscillator signal of the oscillator **15** and the ON/OFF operation of the driver **11** are started. As a result, since the power supply resumes, the charge of the capacitor Co is started.

At time t**7** that a predetermined time has elapsed from time t**5**, the output operation of the oscillator signal of the oscillator **15** is stopped.

At time t**9**, since the output signal from the comparator **21** becomes a low level, and the output voltage Vout exceeds the threshold voltage VTH, that is, the output signal from the A/D converter **17** becomes a high level, the ON/OFF operation of the driver **11** is stopped.

Since the consecutive repetitive number of times is set as "3", at time t**11**, it is determined that the number of times the output operation is consecutively stopped exceeds the consecutive repetitive number of times, and the output operation of the oscillator signal of the oscillator **15** and the ON/OFF operation of the driver **11** are started.

Then, the control mode of the digital control circuit **13** is switched from the low power control mode to the normal control mode at time t**13**. As a result, the output operation of the oscillator signal by the oscillator **15**, and various operations of each component included in the power supply apparatus **10**, for example the ON/OFF operation of the driver **11** and the like are continuously performed.

According to the power supply apparatus **10** of the embodiment, the digital control circuit **13** operates in the normal control mode and in the low power control mode, sets to switch between the normal control mode and the low power control mode based on the current detected by the comparator **21**, and controls the driver **11** and the oscillator **15** based on the set control mode. Therefore, it is possible to reduce the power consumption for the period when the power supply apparatus operates in the low power control mode. For example, when the power consumption in the normal control mode is 1 (μW), it is possible to reduce the power consumption up to about 100 (μW) in the low power control mode.

Also, since the digital control circuit **13** controls the driver **11** and the oscillator **15** in the low power control mode when the power consumption of the load **16** is small, and controls the driver **11** and the oscillator **15** in the normal control mode when the power consumption of the load **16** is large, it is possible to reduce the ratio of the power consumption of the power supply apparatus **10** to the power consumption of the load **16**.

Further, since the digital control circuit **13** performs the control operations, it is possible to easily adjust various settings such as a ripple voltage and the switching frequency according to the specifications of the load **16**.

According to the present disclosure, it is possible to provide a power supply method, comprising: a digital control step of performing the ON/OFF control of the driver **11**; an oscillation step of outputting the oscillator signal for performing the ON/OFF control of the driver **11** every constant period; and a current detection step of detecting the output current of the driver **11**. The digital control step has the normal control mode for continuously actuating the output operation of the oscillator signal by the oscillation step and the ON/OFF operation of the driver **11**, and the low power control mode for intermittently actuating the output operation of the oscillator signal by the oscillation step and the ON/OFF operation of the driver.

Also, according to the present disclosure, it is possible to provide the power supply method in which the digital control step may set to switch between the normal control mode and the low power control mode based on the current detected by the current detection step, and the driver **11** and the oscillator **15** is controlled based on the set control mode.

As described above, according to the present disclosure, it is possible to provide the power supply device, the power supply system and the power supply method, which can execute an adjustment by a digital setting and eliminate the need for a redesign according to the specifications or the environment of the equipment (load) to which power is supplied without lowering the efficiency even when a small power is supplied.

Other Embodiment

Although the embodiments of the present disclosure have been described in the above, it should be understood that the description and the drawings which constitutes a part of the present disclosure do not limit the spirit of the present disclosure. Various alternative embodiments and operation techniques of the present disclosure are apparent to those skilled in the art.

It goes without saying that the present disclosure embraces many different embodiments not disclosed herein. Accordingly, the technical scope of the present disclosure is decided by only the subject matters defined in the claims.

In an apparatus for performing a DC power conversion, the power supply apparatus and the power supply method of the present disclosure may be applied to a power conversion apparatus such as a switching power source apparatus for controlling electric power supplied to the load by the ON/OF control of a switching element included therein.

According to the present disclosure, it is possible to provide the power supply device, the power supply system and the power supply method, which can execute an adjustment setting merely with a digital setting (change of parameter or software) and eliminate the need for a redesign according to the specifications or the environment of the equipment to which power is supplied without lowering the efficiency even when a small power is supplied.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the disclosures. Indeed, the novel methods and apparatuses described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the disclosures. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the disclosures.

What is claimed is:

1. A power supply apparatus comprising:

a driver connected to a power source voltage and configured to perform an ON/OFF operation of power supply to a load;

a digital control circuit configured to perform an ON/OFF control of the driver;

a comparator configured to compare an output voltage outputted from an output node of a coil connected to the driver with a predetermined threshold voltage, the output node of the coil being connected to a capacitor; and

an oscillator configured to output an oscillator signal for controlling the driver,

wherein the digital control circuit operates in a normal control mode in which an output operation of the oscillator and the ON/OFF control of the driver are continuously activated simultaneously, and in a low power control mode in which the output operation of the oscillator is intermittently activated and the ON/OFF control of the driver is intermittently activated,

wherein the digital control circuit is configured to operate in an n-bit mode in which the output voltage is converted into a digital voltage value by n-bits and in a 1-bit mode in which the output voltage is compared with the threshold voltage by 1 bit based on a comparison result of the comparator, and

wherein the comparator is configured to compare the output voltage outputted from the output node of the capacitor and the coil with the predetermined threshold voltage in the 1-bit mode, when the low power control mode is set.

2. The power supply apparatus of claim **1**, further comprising:

a current detector configured to detect an output current of the driver,

wherein the digital control circuit is configured to set to switch between the normal control mode and the low power control mode based on a current detected by the current detector.

3. The power supply apparatus of claim **2**, wherein the digital control circuit is configured to operate in the n-bit mode if the current detector detects the output current for the digital control circuit to switch into the normal control mode when the digital control circuit operates in the low power mode, and the output operation of the oscillator signal by the oscillator is continuously activated if the current detector detects the output current for the digital control circuit to switch into the normal control mode when the digital control circuit operates in the low power mode.

4. The power supply apparatus of claim **3**, wherein the digital control circuit is configured to operate in the normal control mode and to activate the output operation of the oscillator if a number of times that the ON/OFF operation of power supply is consecutively and repeatedly stopped reaches a predetermined number of times when the low power control mode is set.

5. The power supply apparatus of claim **1**, wherein the digital control circuit is configured to stop the output operation of the oscillator and the ON/OFF control of the driver when the control mode is switched from the normal control mode to the low power control mode.

6. The power supply apparatus of claim **1**, wherein the digital control circuit is configured to start the output operation of the oscillator when the low power control mode is set and the output voltage is determined to be equal to or less than the predetermined threshold voltage by the comparison result of the comparator.

7. The power supply apparatus of claim **1**, wherein the digital control circuit is configured to activate the output operation of the oscillator and then stop the output operation of the oscillator after a lapse of a predetermined time, when the low power control mode is set.

8. The power supply apparatus of claim **1**, wherein the digital control circuit is configured to operate in the normal control mode and to activate the output operation of the oscillator if a number of times that the ON/OFF operation of power supply is repeated reaches a predetermined number of times when the low power control mode is set.

9. The power supply apparatus of claim **1**, wherein the driver comprises a switching element.

10. A power supply system, comprising:

a power supply apparatus according to claim **1**; and

a load to which power from the power supply apparatus is supplied.

11. The power supply system of claim **10**, wherein the load is a mobile device including anyone of a cellular phone, a smart phone, a personal digital assistant, an optical disk device, a digital camera and a wireless communication device, or components of the mobile device.

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